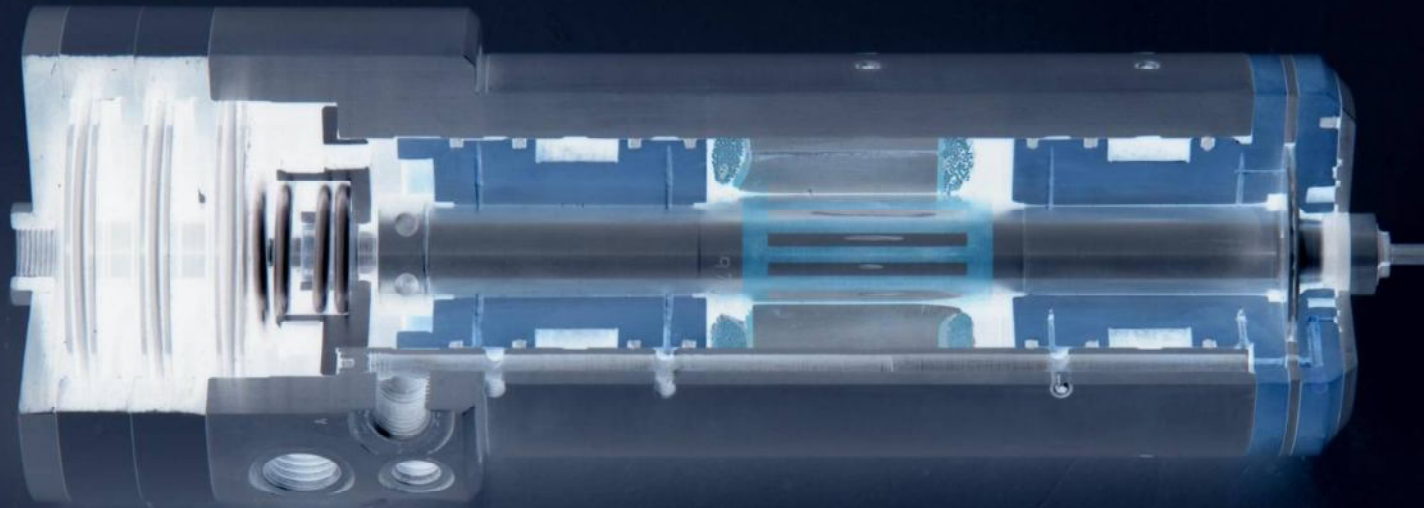


Advances in Mechanical Micro-drilling

The Institute of Circuit Technology: 1st March 2011, Arundel



Chris Gerrard, R&D Manager
Mike Wellstead, Apps Manager



Topics

- Background to PCB drilling market
- What does the market need now & in the future?
- What is the current technology ?
 - Spindles
 - Machines
 - Drills
 - Boards
- What's next in spindle technology?

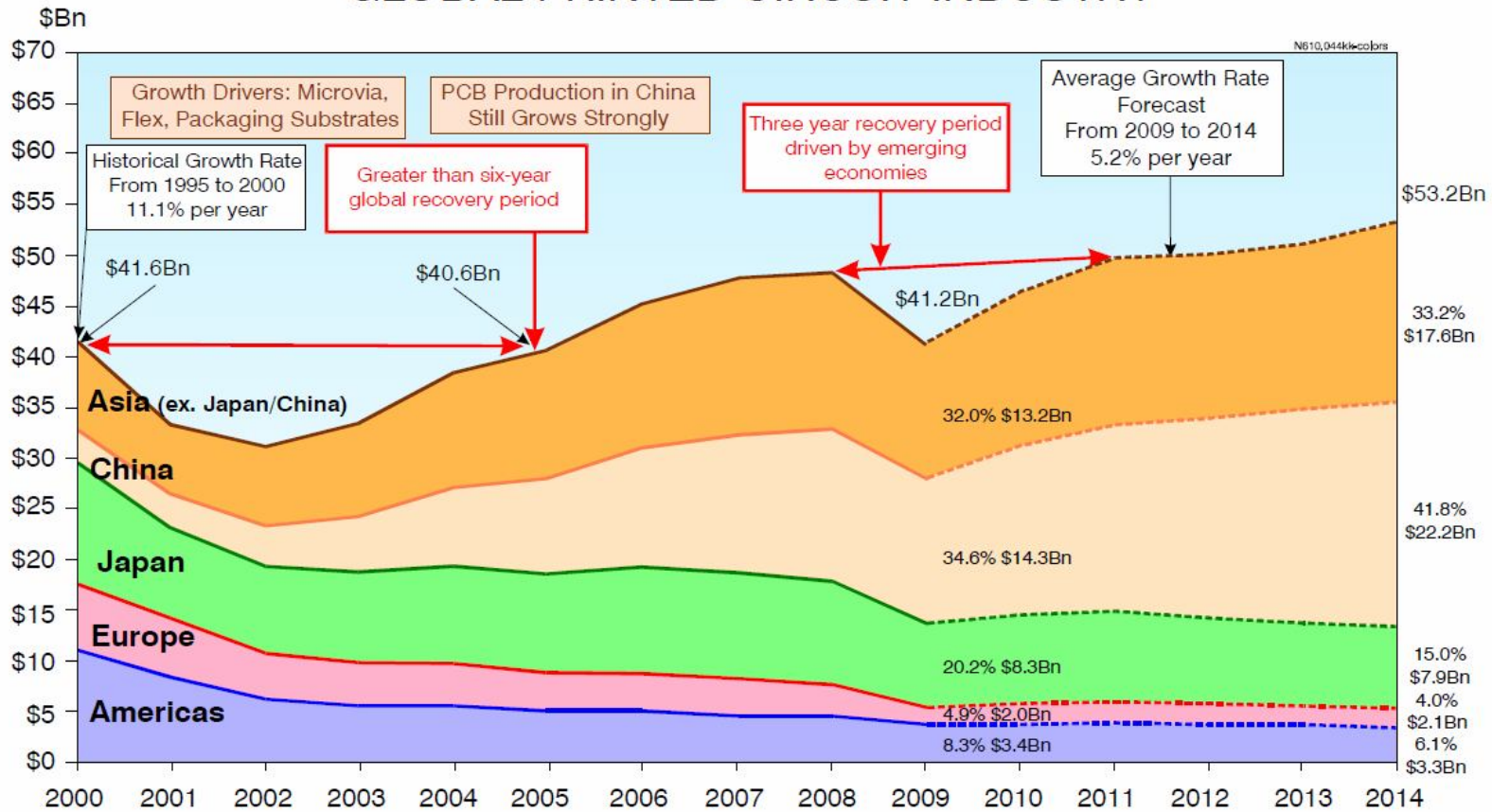


Westwind UK



Westwind China

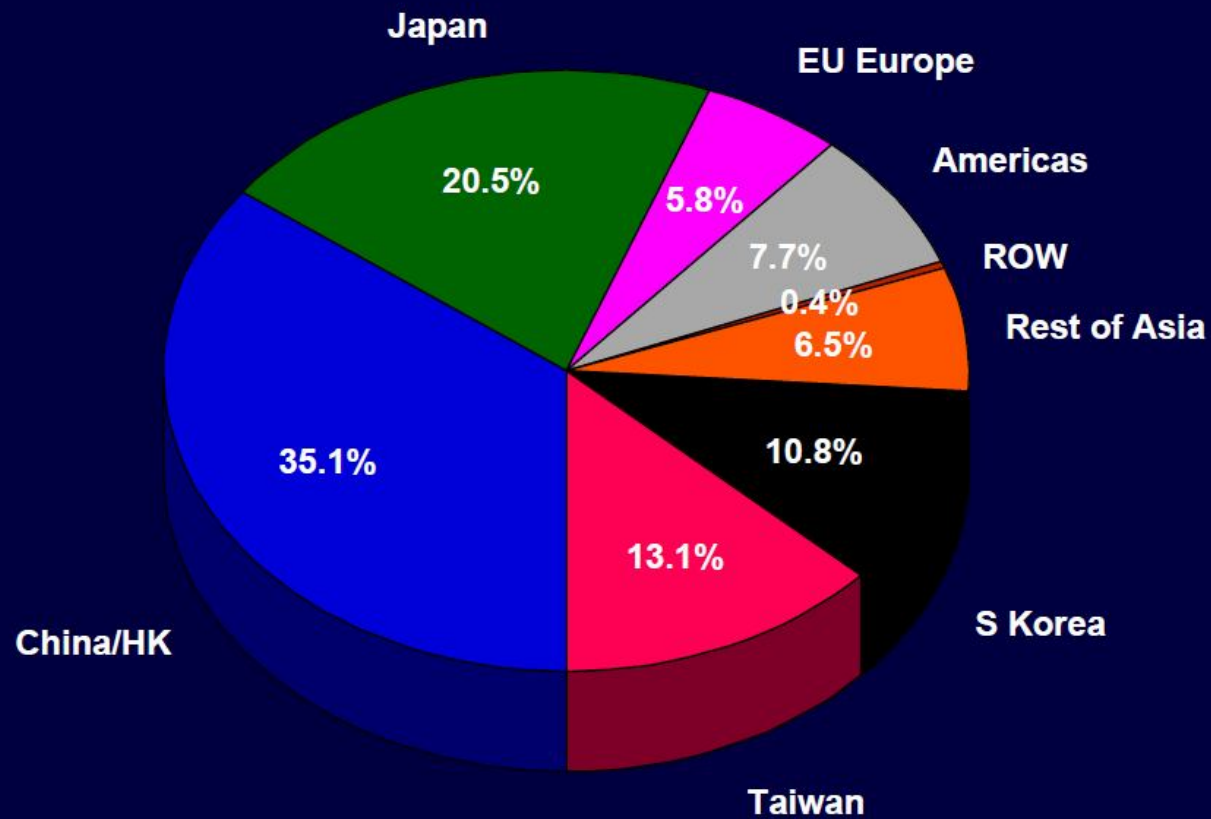
RECENT HISTORY AND OUTLOOK FOR THE GLOBAL PRINTED CIRCUIT INDUSTRY



June 2010_3



2010 World Rigid & Flex PCB Production by Geographical Area



H Nakahara 9/2010

Total: \$52.1 Billion

Courtesy of Custer Consulting

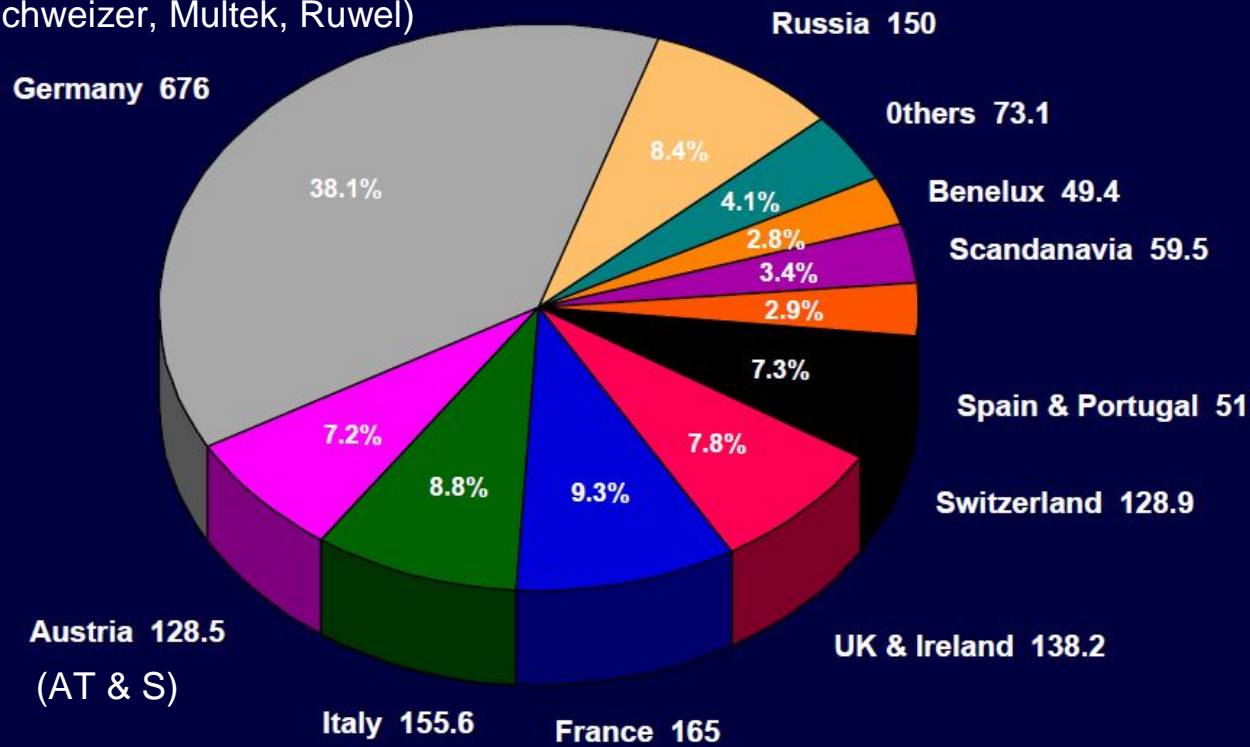
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2009 European Rigid & Flex PCB Production (Euros)

(Wurth, Schweizer, Multek, Ruwel)



Total: 1,825 Million Euros

M Gasch 8/2010 + Custer Consulting Group estimate for Russia

Courtesy of Custer Consulting

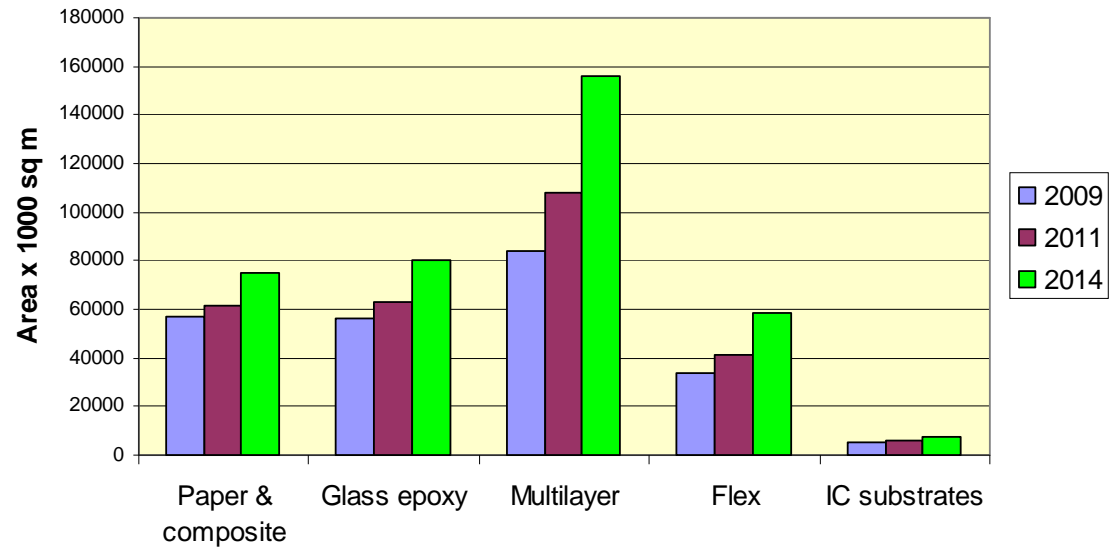
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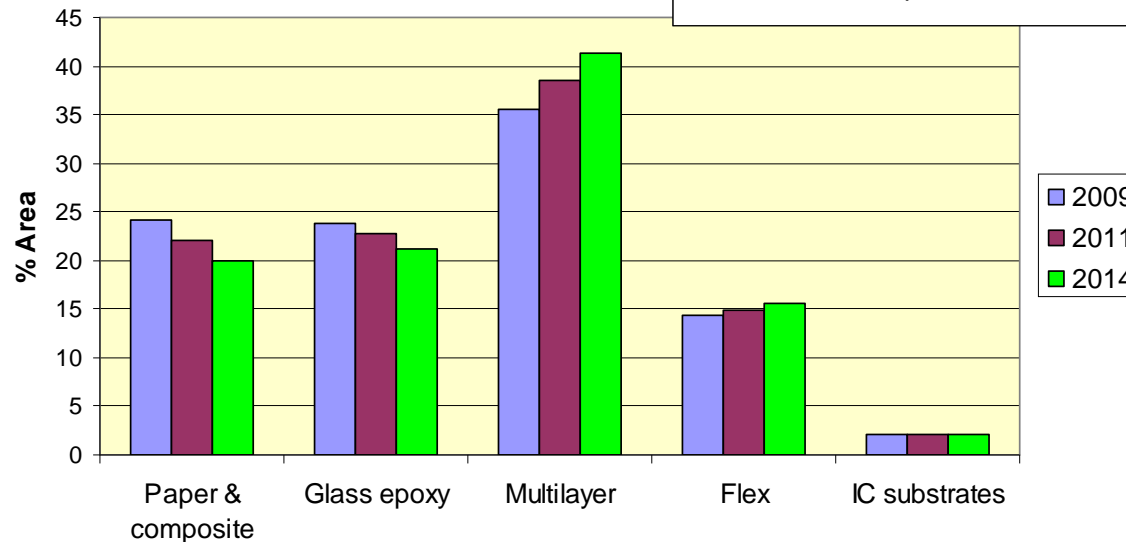
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World finished board area to 2014 – BPA Consulting Ltd

World finished board area actual/forecast to 2014 - BPA Dec 2010



World finished board area, actual/forecast



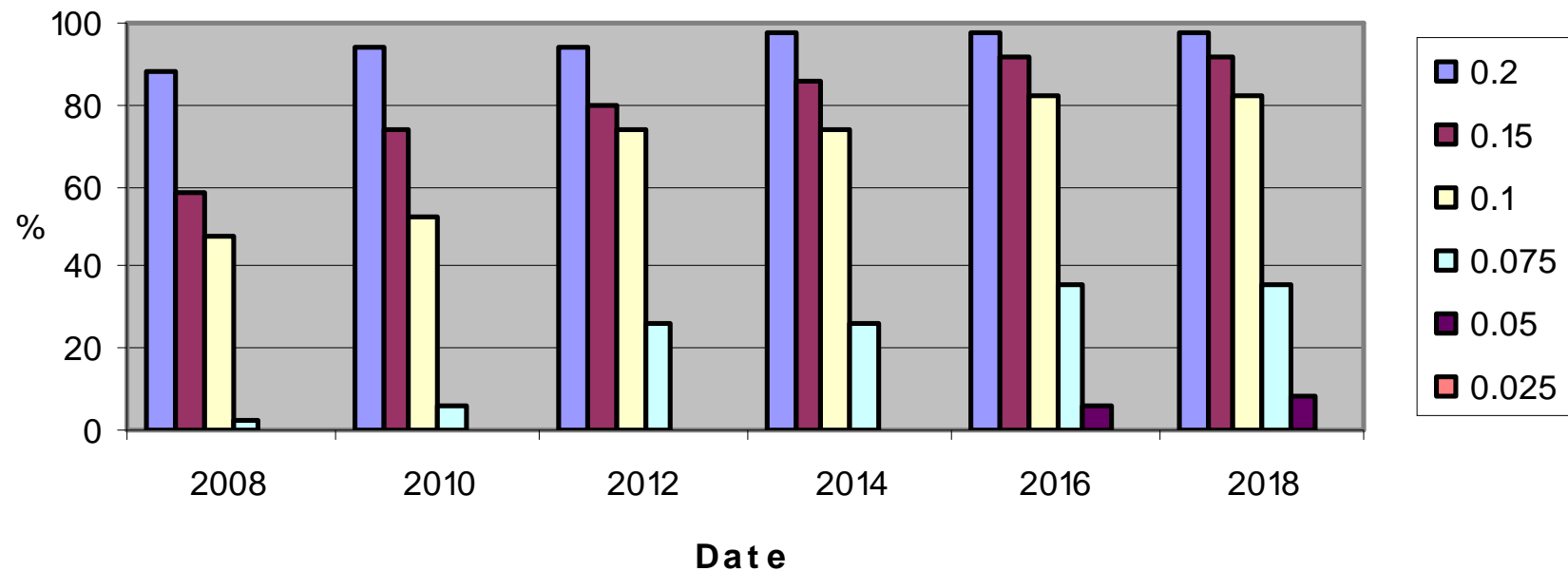
Multilayer board is the largest growth area

JEITA roadmap for PWB hole diameters

(Japan Electronics & Information Technology Industries Association)

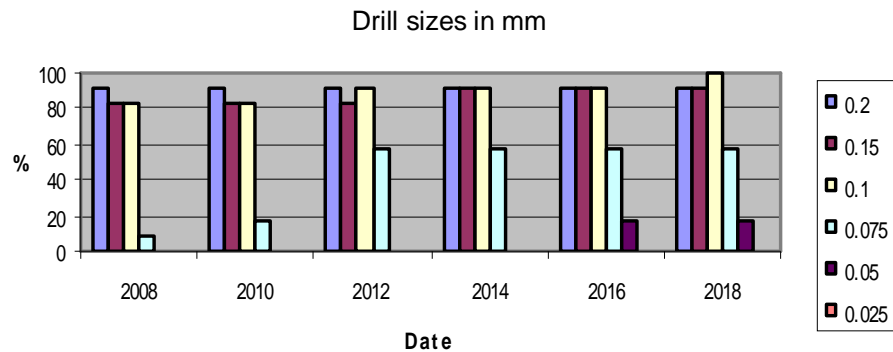
Micro Drill customer usage (forecast) - PWB

Drill sizes in mm

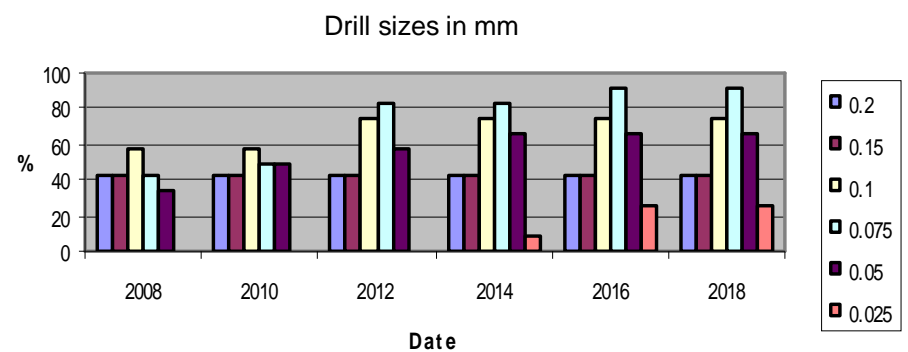


JEITA roadmap for Substrate hole diameters

**Micro Drill customer usage (forecast)
- Package substrates (mechanical)**

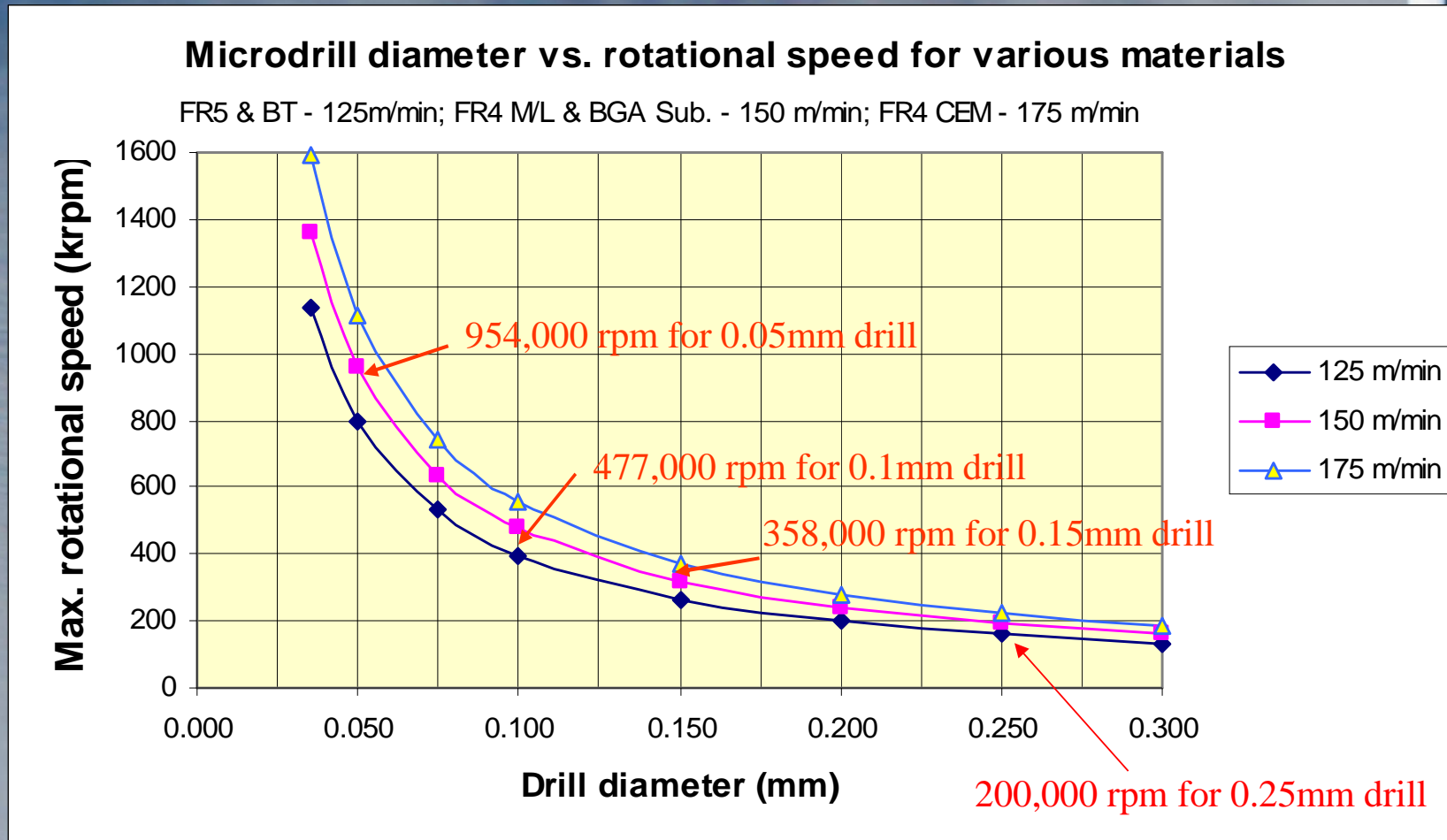


**Micro Drill customer usage (forecast)
- Package Substrates (LASER)**



Even in packaging, 50 microns will be the limit of mechanical drilling

Microdrill diameter vs. ideal rotational speed – future needs



Speed is King: The need for very high speed spindles

The correct cutting speed gives demonstrated lower running costs through:

- Longer tool life

0.1mm dia: S200, 3000 hits => S300, 6000 hits

- Less tool breakage

0.1mm dia: S200, 0.01% => S300, 0.005%

- Improved hole quality

- Higher productivity in volume manufacture:

– 0.1mm dia. S200, 560hits/min => S300, 700 hits/min

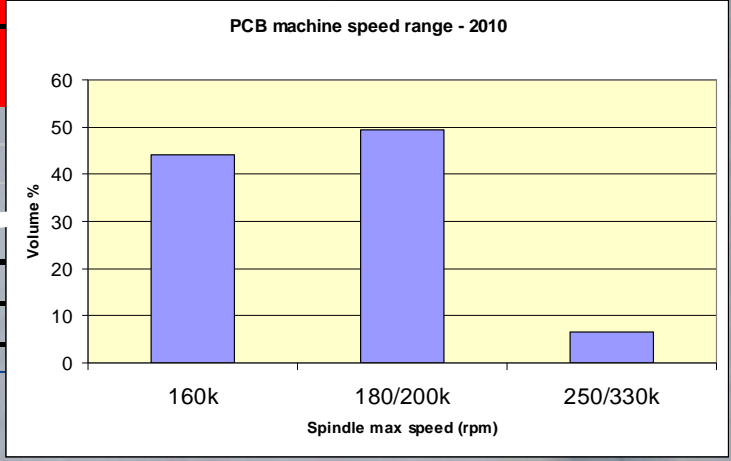
– Next generation machines will achieve 850-1000 hits/min

Europe & Japan lead the technology race

Drilling machine market 2010

(based on spindle sales)

Machine model	Machine type - drilling				Machine type - drill/routing		
	Standard 20-160k rpm	Extended 20-180k rpm	Premium 20k-200k rpm	Micro-drilling 30k-250/330k rpm	Standard 20-80k rpm	Extended 20-125k rpm	Premium 20-150k rpm
Application	Motherboard	M/L + HDI	M/L + HDI	BGA/CSP	General	General	small pocket
Schmoll	Y	Y	Y	Y		Y	Y
Posalux		Y	Y	Y		Y	
Lenz			Y	Y		Y	
HVM	Y		Y	Y (330k)	Y (b/b)	Y	
Roku-Roku		Y	Y	Y			
Tong Tai	Y	Y	Y	Y (250k)	Y		
Ta Liang	Y	Y	Y		Y (b/b)		
Takisawa	Y		Y		Y (b/b)	Y	
Anderson	Y	Y			Y (b/b)		
Hans CNC	Y	Y	Y				
Timax	Y	Y	Y				
Mantat		Y					
Qianghua	Y	Y					
Vega	Y	Y					
Others	Y	Y					
% of market	44	22	27.5	6.5			



Note some missing familiar names:
 Excellon, Mania, Pluritec

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Current industry leading spindles for full range drilling & micro-hole drilling



D1822 spindle

- Speed range: 20k to 200k rpm
- Drill range: 6.35mm to 0.15mm dia.
- Collet size: 1/8" dia.

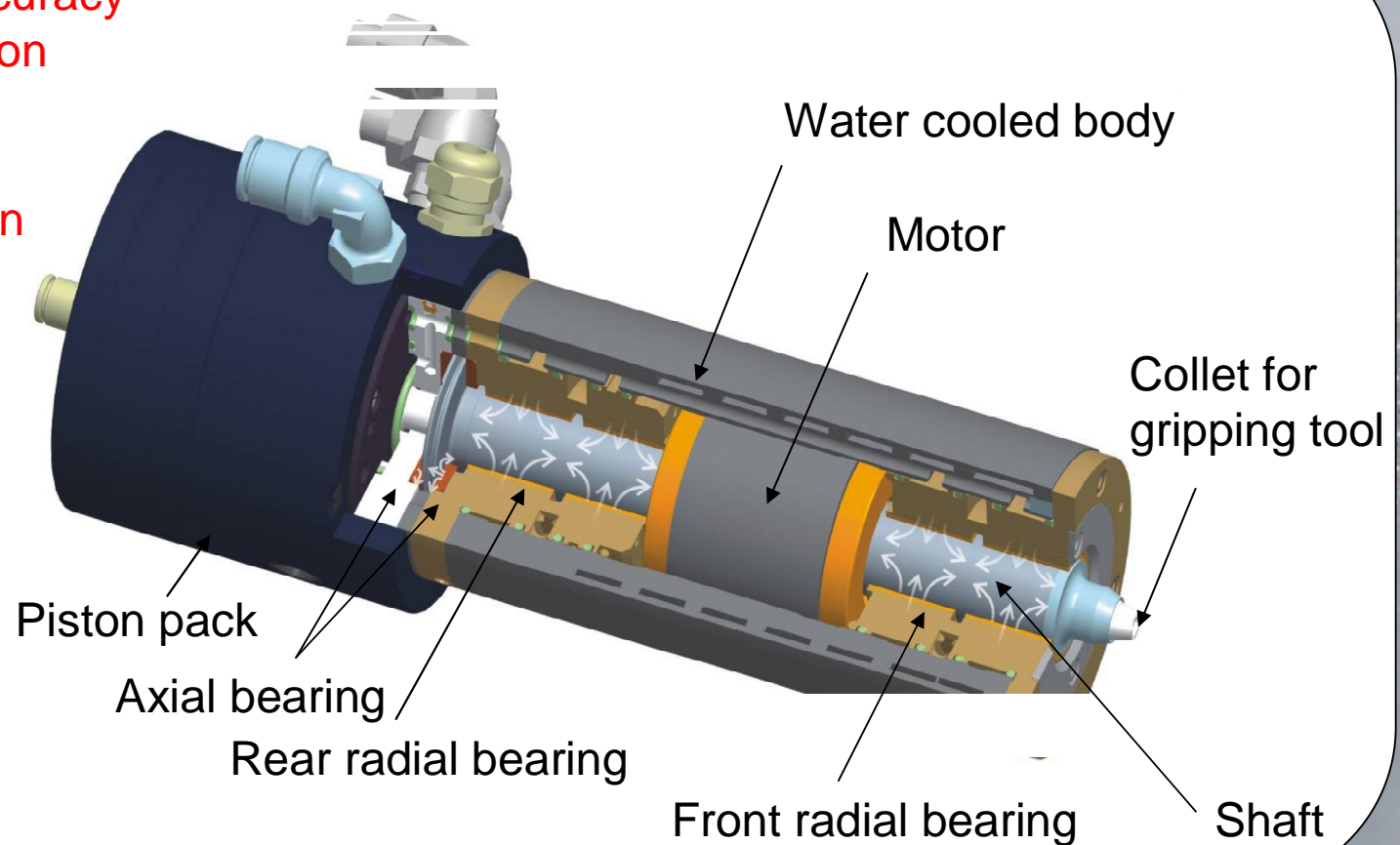


D1790 spindle

- Speed range: 30k to 285k rpm
- Drill range: 3.2mm to 0.05mm dia.
- Collet size: 2mm or 1/8"

High speed air bearing spindle cross-section

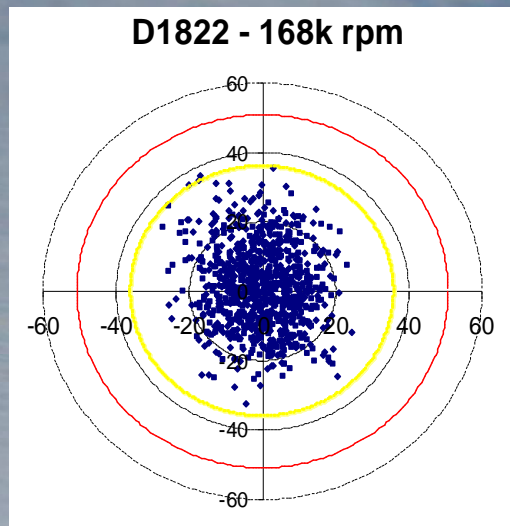
- Very high rotational speed
- Low vibration
- High rotational accuracy
- Low heat generation
- High stiffness
- Long lifetime
- Zero contamination



Current industry issues - Cpk drilling accuracy & large hole burr heights (using D1822 200k full range spindle)

Drilling Accuracy (bottom board)

$Cpk=1.8$; $3\sigma=36\mu m$

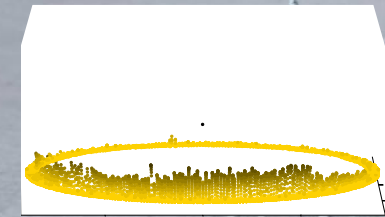
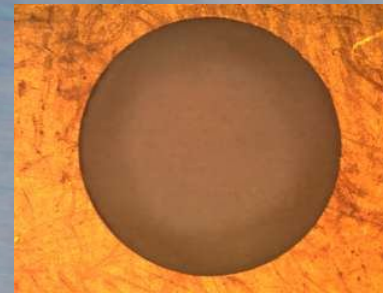


— 3σ

— Upper Specification Limit

3D laser profilometer burr measurements

6.35mm dia. hole, 20k rpm, 0.8m/min feed



Average burr height ~ 10 microns;
Max burr height ~ 16 microns

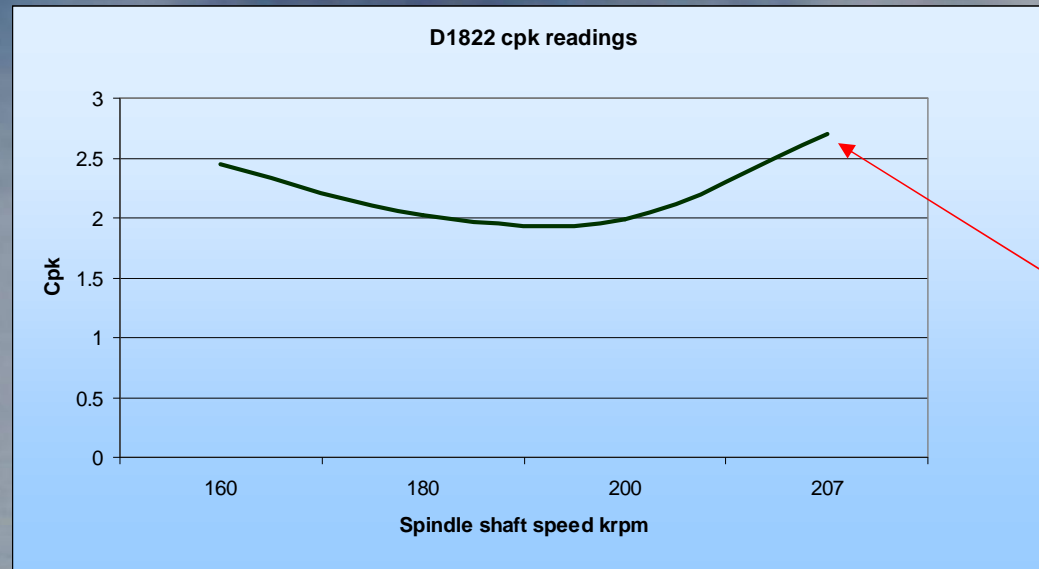
Industry leading results

- Panel: t1.6mm FR4 (Cu35u0) x 2 high
- Entry: 0.2mm Al
- Drill: 0.35mm dia.

Spindle Speed: D1822 -168k rpm
Drilling Speed: 3.3m/min infeed
Drilled holes: 920

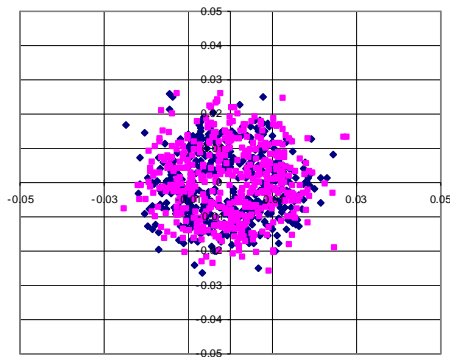
• Measurements taken using Nikon VMR3020

D1822 Cpk between 160k & 207k rpm

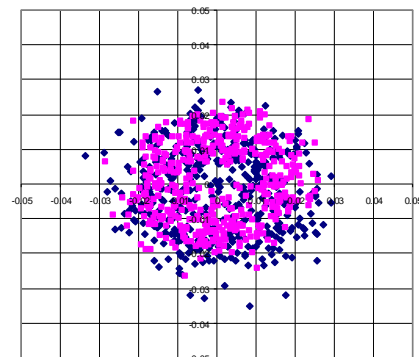


Overspeed test

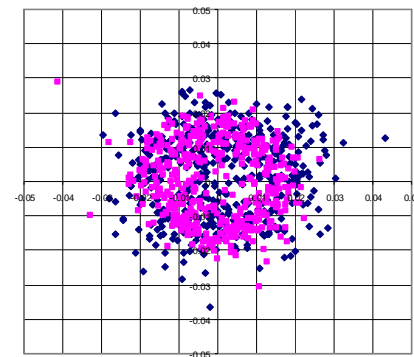
D1822 160k entry



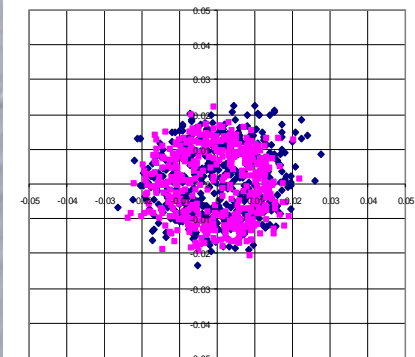
D1822 180k entry



D1822 200k entry



D1822 207k entry



Drilling machines - what are the challenges in HDI/BGA?

How can 500'000 micro-holes be drilled in 8 hours ?

ie = 1000 hits per minute, 5 panels high, 0.1mm thick, with a 0.1mm dia drill

Z-axis improvements	<u>Previous</u>	<u>Latest</u>
Acceleration	10 m/s ²	15 m/s ²
Jerk time	8 ms	5 ms (time to reach acceleration)

Decrease drilling stroke using improved micro-pressure foot (no air drilling !)

Stiffer machine design – structure & mechanics

High speed spindles - 300k+ rpm & dual head station

Improved heat management – machine & environment



Data courtesy of Posalux

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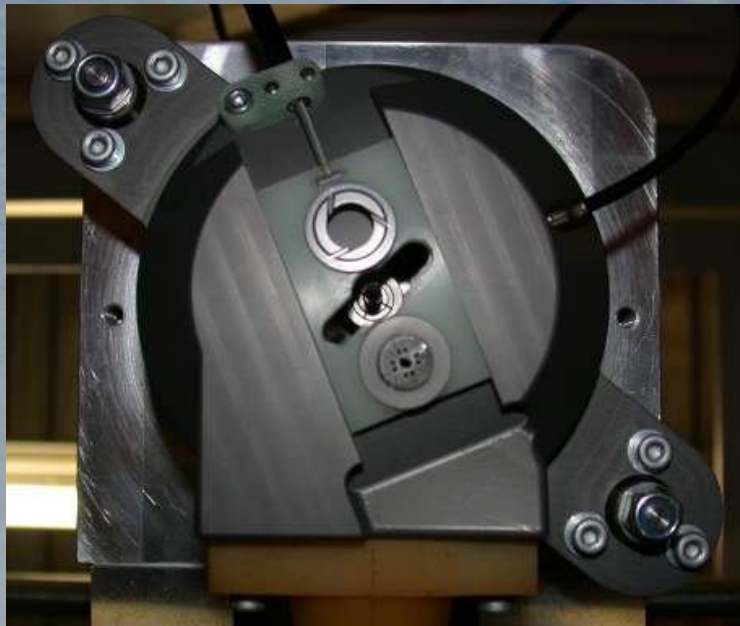
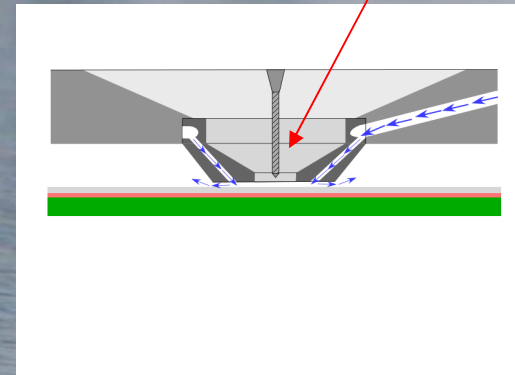


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3 position micro-pressure foot

- Holds the entry foil nearer to drill bit
- Insert for small hole drilling
 - 1.5 mm opening, active from $\varnothing 0.7\text{mm}$
 - Increased accuracy because of closed insert
- Large opening for large diameters

Need airflow around tool
Especially at bottom of stroke



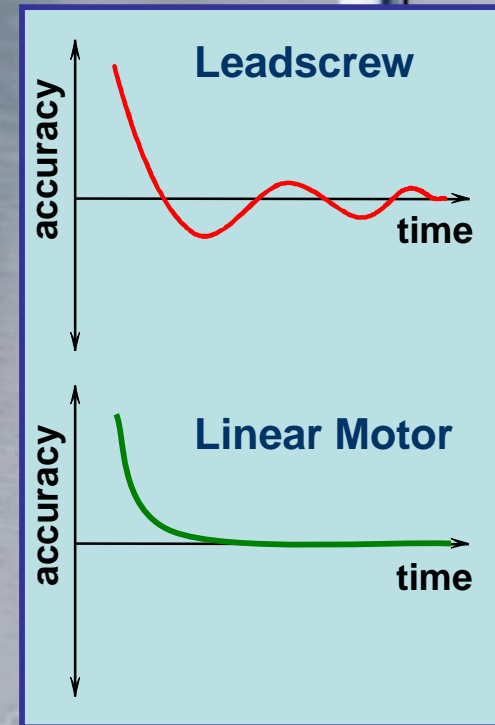
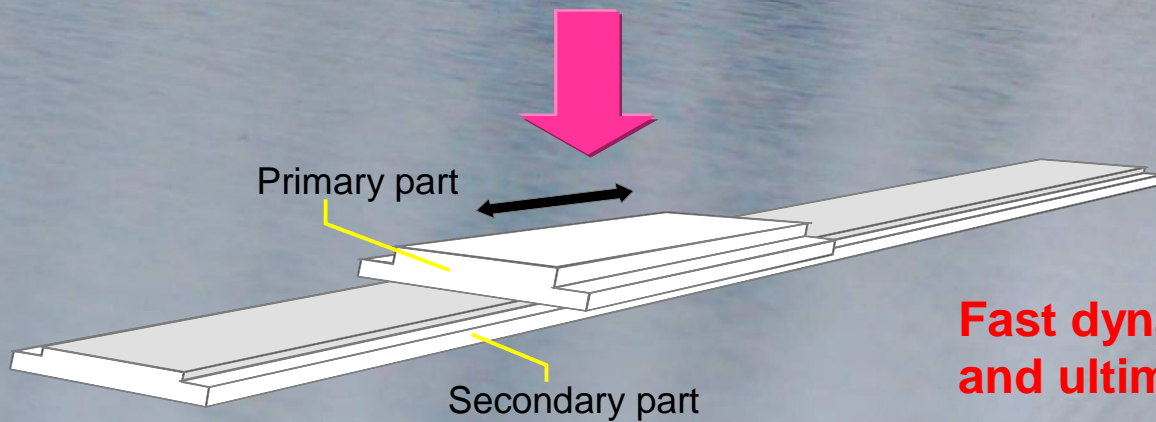
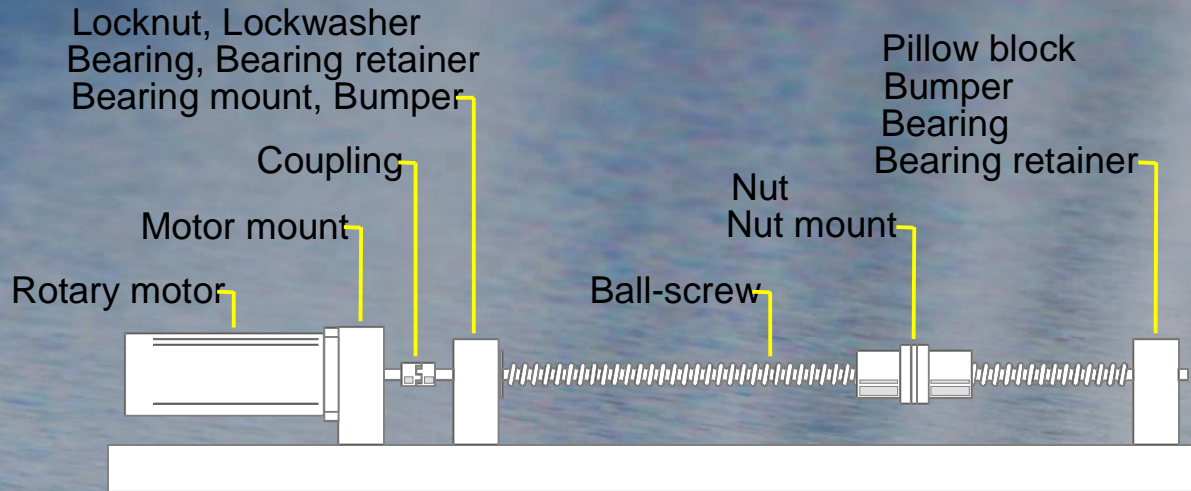
Data courtesy of Posalux

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Improved stiffness between ball screw and linear motor due to minimal mechanical parts with optimum digital servo control technology



**Fast dynamics, high productivity
and ultimate in accurate drilling**

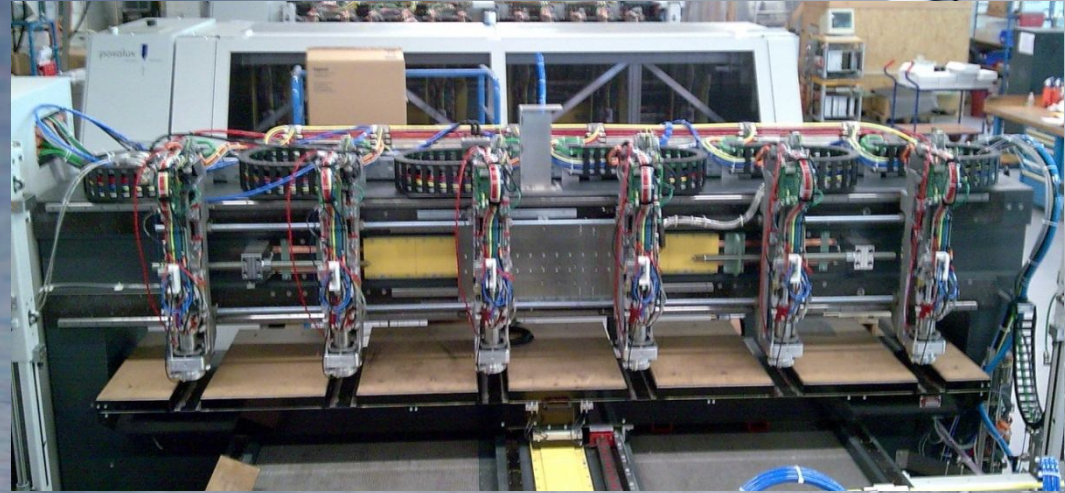
Data courtesy of Posalux

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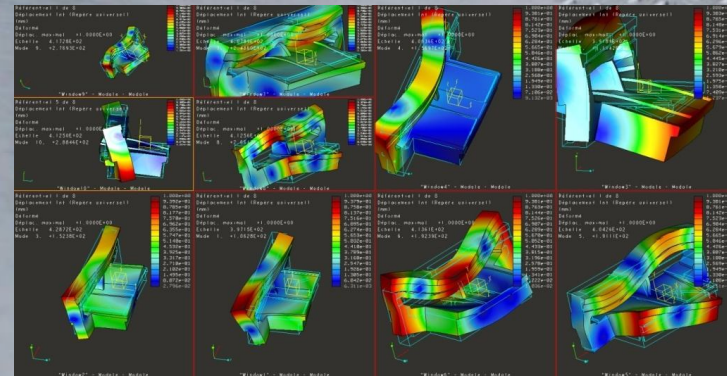


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Stiff machine base ensures low vibration - FEA and modal analyses



Synthetic granite base & cross-beam



Data courtesy of Posalux

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Temperature management – effect on machine & board

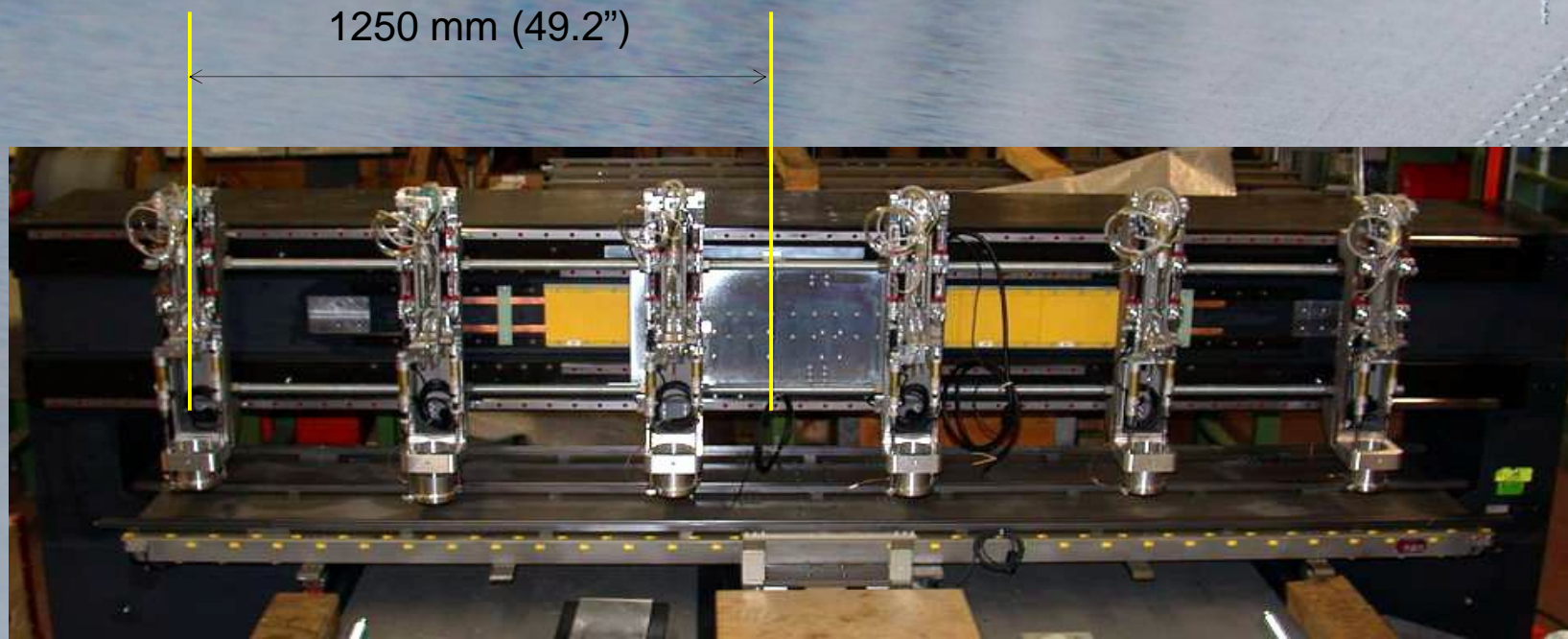
Linear thermal expansion coefficient

- Influence of 1°C temperature change:

X Axis/table: $12\mu\text{m } ^\circ\text{K}^{-1} \text{m}^{-1} \cdot 1^\circ\text{K} \cdot 1.25\text{m} = 15\mu\text{m} (0.6 \text{ mil})$

Panel: $16\mu\text{m } ^\circ\text{K}^{-1} \text{m}^{-1} \cdot 1^\circ\text{K} \cdot 0.610\text{m} = 10\mu\text{m} (0.39 \text{ mil})$

$16\mu\text{m } ^\circ\text{K}^{-1} \text{m}^{-1} \cdot 1^\circ\text{K} \cdot 0.457\text{m} = 7.3\mu\text{m} (0.29 \text{ mil})$



Data courtesy of Posalux
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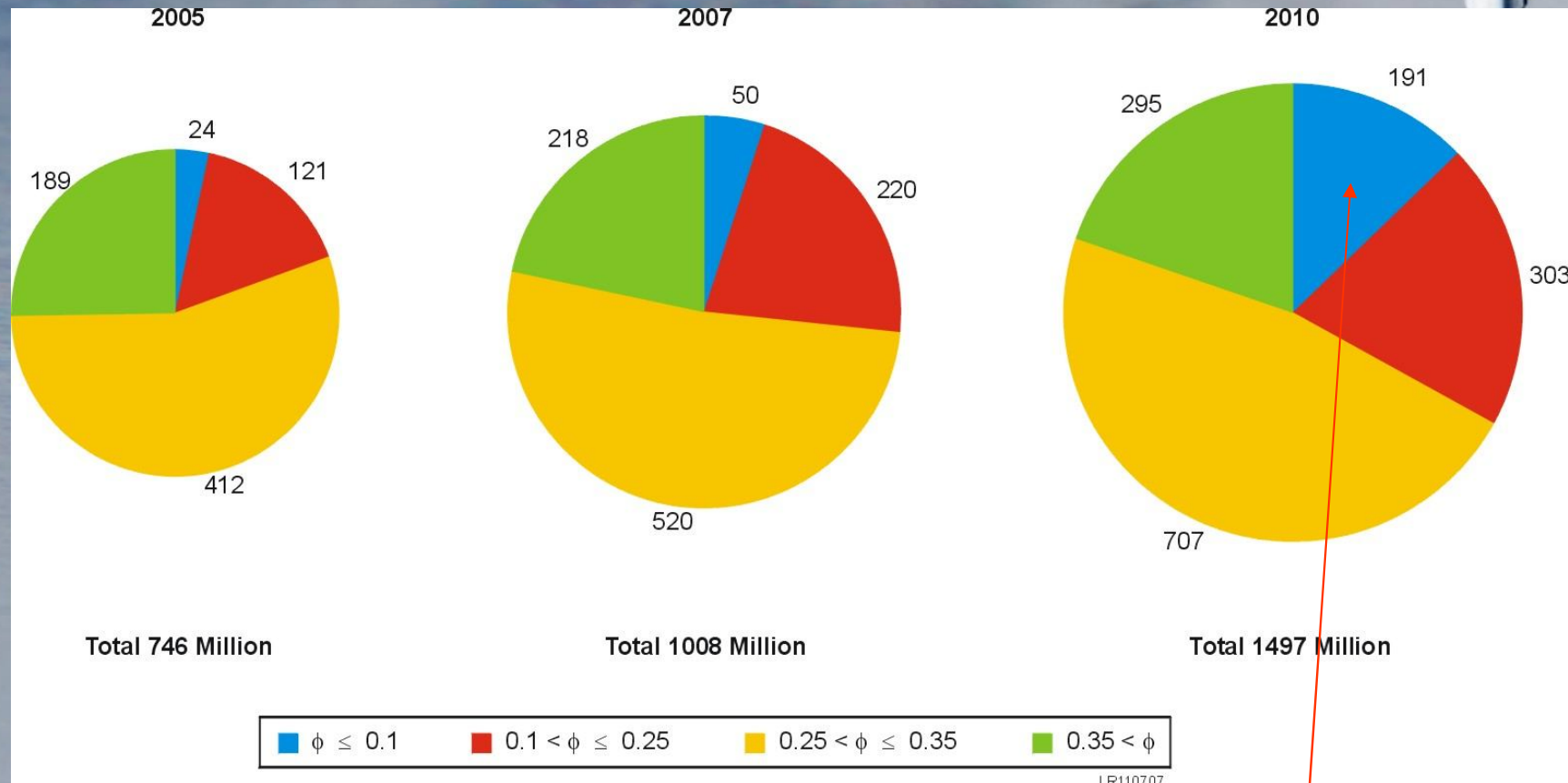


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Drill Technology

– the move to smaller drill diameters

World Total Sales by Volume Drill Bit Diameter - BPA

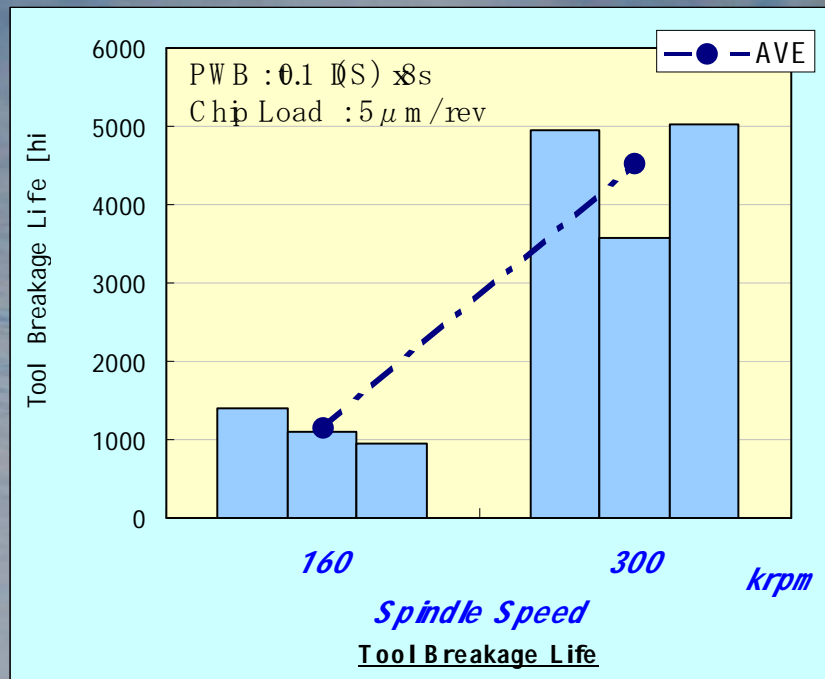


Large % increase over 2007

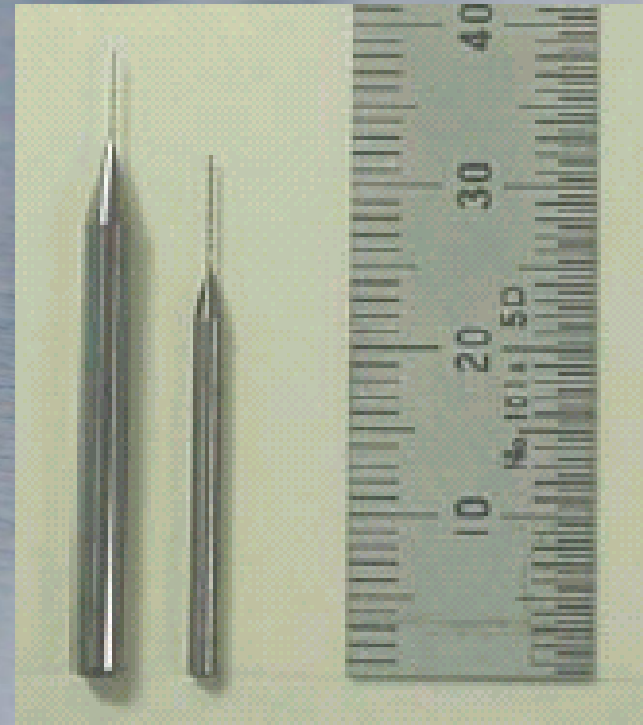
UT 2mm shank: 0.1mm dia tool data

300,000rpm !

2mm Shank Drill



0.1 (D/S) x 8stacks, Drill 0.10mm



L : Normal 1/8' Shank with 1.5' OAL
R : 2mm Shank with 1.25' OAL

UNION TOOL CO.

2000 ZPC-A SIZE HP

量産中

φ 0.050 Ultra Micro-Hole Drilling Performance

φ 0.050 鑽頭加工事例

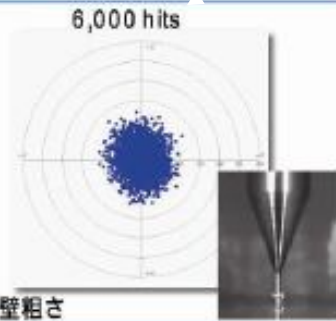
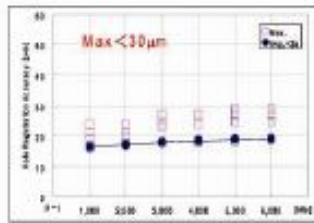
用途：半導体封裝基板用、各種電子元件用基板等 FBGA、BGA、Device substrate etc...

Drilling Condition 加工條件

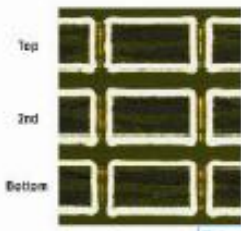
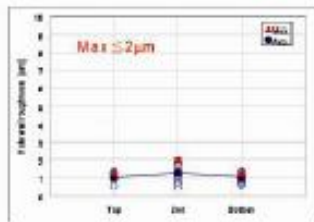
Work Material : BT CCL-HL832HS t 0.1(Double Sided) x 3 stack height 3/3μmCopper
 S : 350,000 min⁻¹ F : 1.75 m/min f : 5 μm/rev
 Set Life : 6,000 hits

High Quality & High Efficiency Drilling
 實現高品質 & 高效率加工

Hole Registration Accuracy 孔位精度



Hole Wall Quality at 6,000 hits 内壁粗さ



Patent Granted
 in Japan

FOR HUMANITY, FOR THE FUTURE



UT 2mm shank: 0.05mm dia. drilling data

Up to 6000 hits

300,000 rpm, 2.25m/min

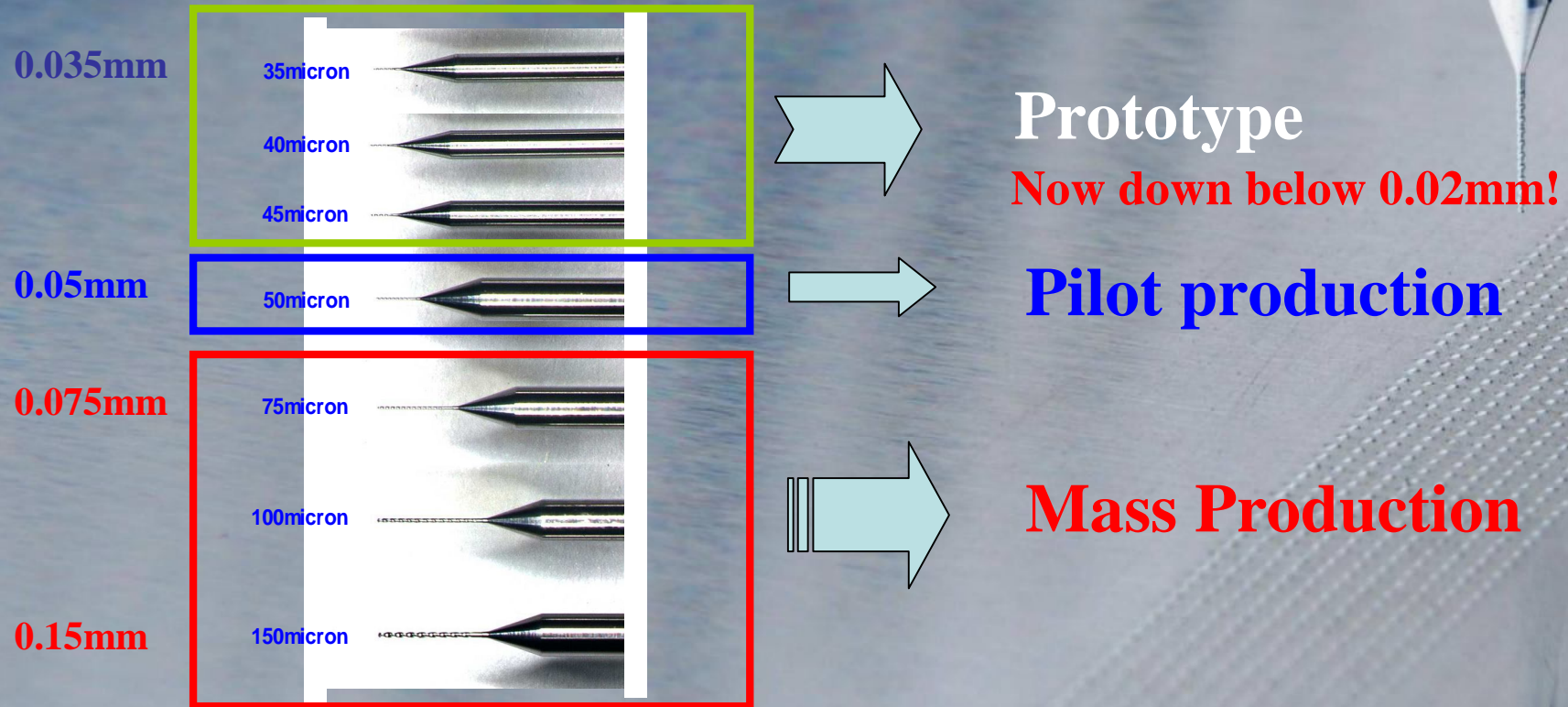
ドリル切削条件 Parameters

φD mm	刃長 flute length mm	送り速度 Feed rate mm/min	チップロード Chip load μm/rev	RUL寿命 HL Count ¹⁾	回転速度 Velocity rpm	基板厚さの目安 Board Thickness and Stack Height	
						層数 Layers	層高 Stack Height
0.075	300	1.50	5.0	2000	71	02.1(両面銅 double-sided board 5-5 μm)	4
0.09					85		5
0.10		94	6				
0.12		113	8				
0.15		141	10				
0.20	250	2.40	10.0	2500	157	02.4(両面銅 double-sided board 12-12 μm)	4
0.25	300				12.0		6
0.30	350	15.0	141		8		
0.40	450	20.0	151				
0.50	600	30.0	161				
0.60	750	45.0	163				
0.70	900	60.0	151				
0.80	100	1.10	10.0	2000 *2	155	02.4(両面銅 double-sided board 12-12 μm)	8
0.90	110				141		
1.00	120	155					
1.10	130	161					
1.20	140	179					
1.30	150	0.80	20.0	1000 *2	163		
1.40	160				167		
1.50	170	179					
1.60	180	192					
1.70	190	209					
1.80	200	0.70	20.0				

¹⁾ 寿命の目安。加工条件により多少の差が生じます。詳細はお問い合わせください。
²⁾ 詳細はドリルとワークの両者の仕様（フリット径、送り速度）に依存して異なります。
³⁾ 0.2mm以下の径はドリルチップの寿命が短くなる可能性があります。
 Chip load and HL count may vary depending on the board type, material and stack height.
 HL count should be set in accordance with the application or condition of the drilling condition and material recommendations.
 For diameters over 0.2mm please refer to the machine maker's recommendations.

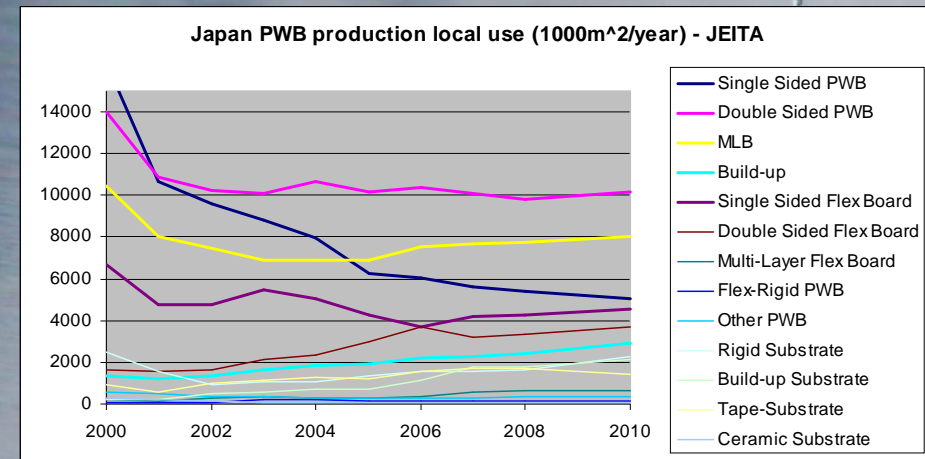


UT - Increasing demand of micro-mechanical drilling



Drilling new board materials

- Halogen-free board adoption will continue from about 30% today to about 60% by 2013 – harder (slower) to drill due to additives (silica, powdered ceramic, etc), implying more machines needed for same board output
- High Tg materials appear to cause greater tool wear & have the potential for creation of finer/more abrasive swarf, which could be an issue with the spindle collet & the pressure foot
- Lubricated entry materials for use with micro-drills in BGA work, such as LE400/800 – the vapourised lubricant can get up into the spindle and cause problems. Also CpK can be affected if material is too thin



The move from lower tech to higher tech boards in Japan

What's next in WW spindle technology ?

370k rpm DC small hole drilling spindle

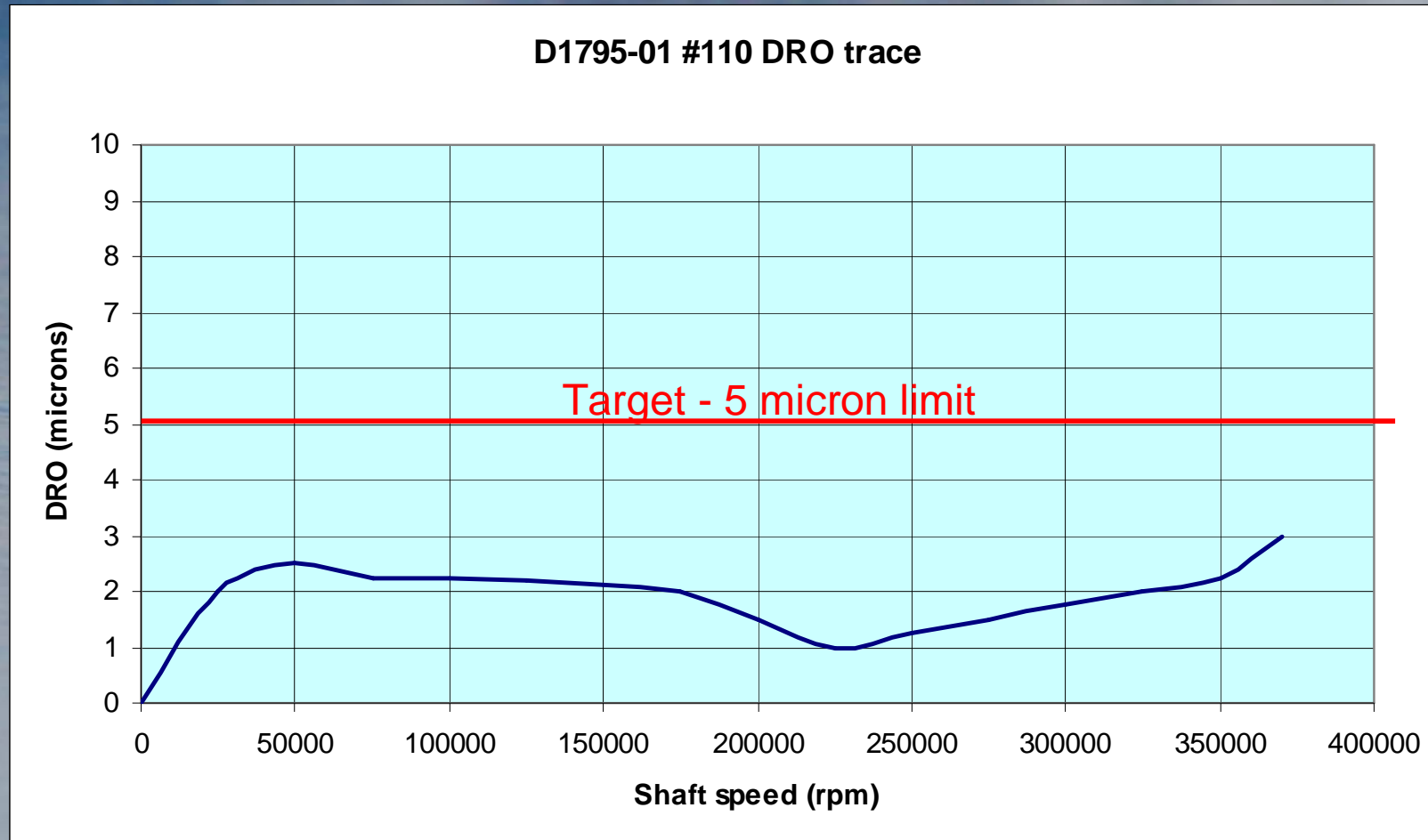
Next generation spindle for BGA & HDI markets with greater speed range and larger hole capability

- Permanent magnet DC motor
- 370k rpm real shaft speed
- Ultra fast acceleration
- 2mm and 1/8" collet options
- 4 mm hole capability - single shot
- Ultra low DRO

Available end 2011/early 2012

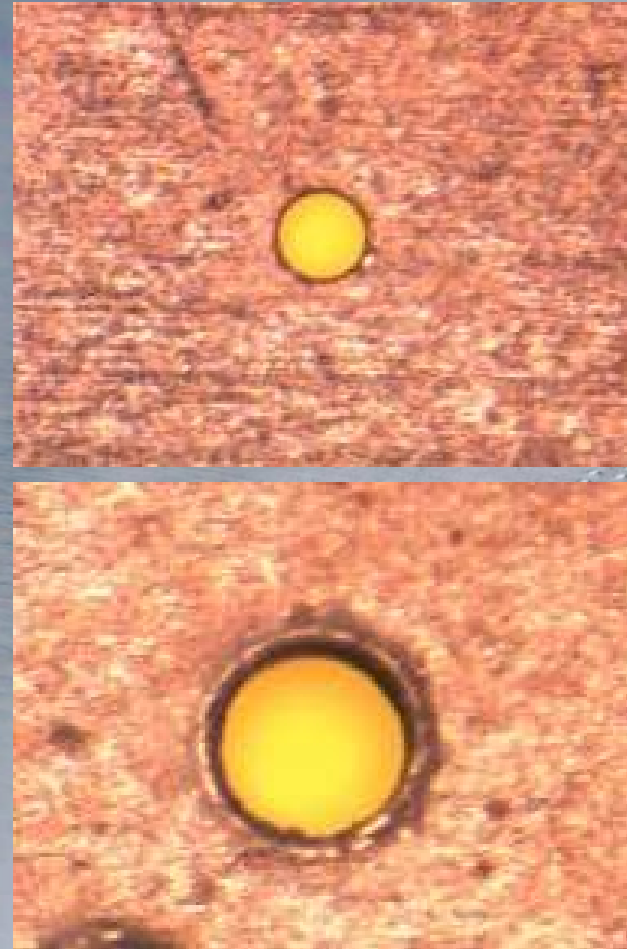


370k rpm spindle DRO trace with 1/8" collet



Initial application testing

- 0.05mm dia, 370k rpm
 - In-feed: 0.5m/min
 - Material: 0.1mm thick HL832HS 12/12 CCL
 - Layers: 3
 - Entry material: LE800
-
- 0.1mm dia, 350k rpm
 - In-feed: 0.5 m/min
 - Material: 0.15mm thick HL832HS 12/12 CCL
 - Layers: 3
 - Entry material: Al foil

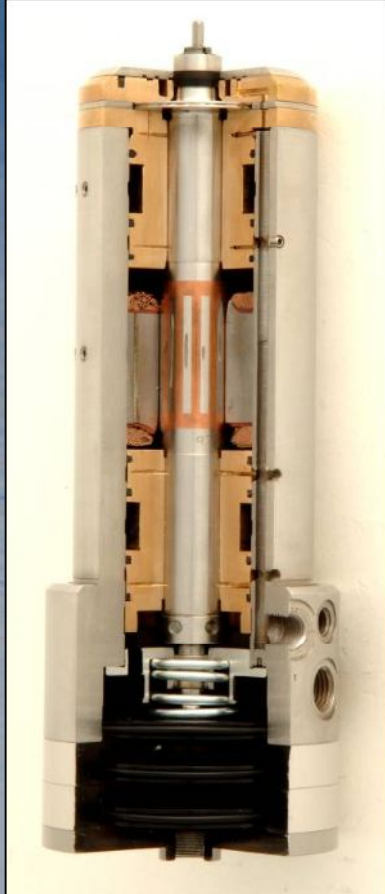


Design issues to face at very high speeds – at 400k rpm & beyond

- Ability to grip tool due to centrifugal forces pulling the collet jaws apart at max speed
- Controlling DRO through the speed range to minimize micro-drill tool breakage
- Maintaining enough motor torque at low speeds to drill larger holes – even 3.2mm dia. can become an issue
- Resisting the higher G forces applied by the linear motors to achieve greater hit rates
- Improving tool designs to prevent critical resonances due to slender L/D ratios – maybe only 1.6mm shank too

Mechanical versus laser drilling in the future

- The battleground on hole diameter will be between 50 & 100 microns, above which mechanical drilling will still dominate for many years
- Below 50 microns, laser drilling will remain exclusive due to the much lower cost-per-hole
- Hence, production drilling spindles above 450/500k rpm will be unlikely to be needed
- High end IC substrates will move to coreless technology, favouring laser technology (currently mechanical drilling is still widely used in both CSP & BGA cores)
- The trend for thinner copper plating (12 rather than 18 micron) for next generation IC's products will favour laser drilling
- However, the trend for thicker copper plating in power applications (auto & comms markets) favours mechanical drilling



Thank you for listening
Any questions ?

Or meet us in the bar
afterwards for a chat !

cgerrard@gSIG.com